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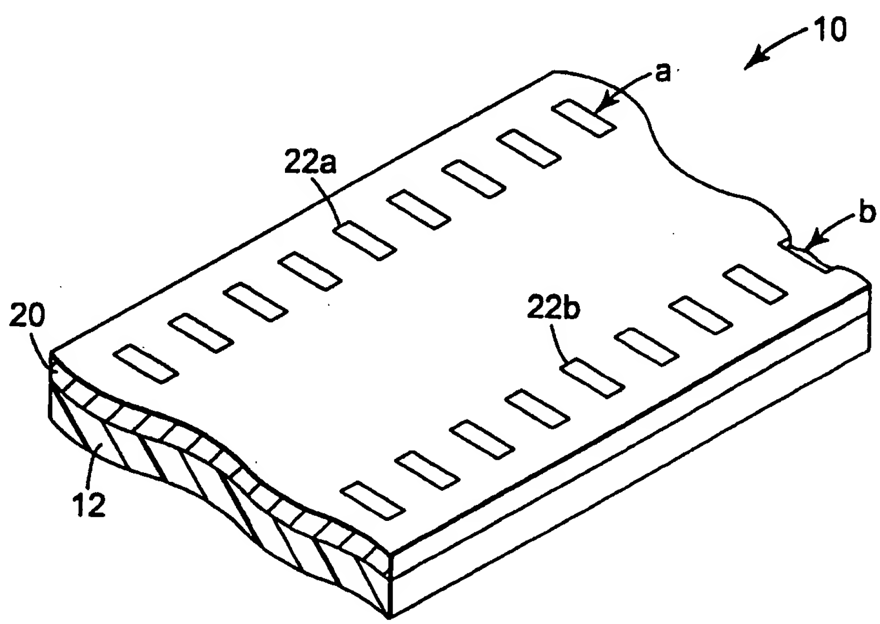

(57) Abstract

Magnetic data storage tapes with etched servo patterns are disclosed along with methods of manufacturing the tapes. The servo tracks formed by etching may be read magnetically by magnetically overwriting a pattern etched into a magnetic coating on the tape, followed by detecting the electromagnetic modulation caused by the servo pattern etched into the magnetic coating. The etched servo pattern may also be read ptically in addition to magnetically, with the optical writing occurring simultaneously, sequentially or both simultaneously and sequentially. Whether the servo tracks are read magnetically or magnetically and optically, the electromagnetic and/or electromagnetic/optical modulation caused by the etched pattern can be used to accurately position a read/write head on the tape.

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MAGNETIC DATA STORAGE TAPE WITH ETCHED SERVO TRACK

Field of the Invention

The invention relates generally to the etching of servo tracks on magnetic data storage media. More particularly, the present invention relates to etched servo tracks on magnetic data storage tape, methods of forming the etched servo patterns, and methods of positioning read/write heads using the etched servo tracks.

Background

Servo patterns are used to control movement of read/write heads over magnetic data storage media where the media is provided in the form of a circular disk or a tape. The servo tracks on conventional data storage tapes are provided by magnetically encoding the magnetic coating provided on the substrate of the media.

One problem with magnetic data storage tapes is that, because the servo tracks are magnetically encoded, bulk erasing of the magnetic data storage tapes not only erases the data stored on the tapes, it also erases the servo-tracks. Erasure of the servo tracks renders the tapes useless for data storage purposes because proper positioning of the read/write heads can no longer be ensured.

Furthermore, the magnetically-encoded servo tracks are formed using specialized servo-track writing equipment. Reformatting of the tapes after, e.g., bulk erasing has destroyed the original servo tracks, typically requires use of the same specialized equipment which is not widely available. As a result, magnetic data storage tapes including magnetic servo tracks are typically discarded after bulk erasure has destroyed the magnetic servo tracks.

Another disadvantage of magnetic servo tracks on magnetic data storage tape is that the equipment required to write the magnetic servo patterns is costly and can only operate at relatively low speeds, thereby limiting throughput.

Summary of the Invention

The present invention provides magnetic data storage tape with etched patterns in the tape that are used to provide servo tracks. The present invention also includes methods of providing the servo tracks. The servo tracks formed by etching may be read magnetically by magnetically overwriting a pattern etched into a magnetic coating on the tape, followed by detecting the electromagnetic modulation caused by the servo pattern etched into the magnetic coating. The

etched servo pattern may also be read optically in addition to magnetically, with the optical writing occurring simultaneously, sequentially or both simultaneously and sequentially. Whether the servo tracks are read magnetically or magnetically and optically, the electromagnetic and/or electromagnetic/optical modulation caused by the etched pattern can be used to accurately position a read/write head on the tape.

Advantages of the present invention include the ability to provide permanent optical servo tracks. Alternatively, if a magnetic servo track is formed in connection with an etched pattern, the present invention provides the ability to reformat magnetic data storage tapes without specialized equipment. That ability to reformat allows users to bulk erase the magnetic data storage tapes without irreversibly destroying the servo tracks because the tapes can be reformatted by magnetically writing over the etched pattern to restore a magnetically encoded servo track to the tape.

In one aspect, the present invention provides a magnetic data storage tape including a magnetic coating on at least one surface of a substrate and a servo pattern including a plurality of etched regions in the magnetic coating on the tape substrate, the plurality of etched regions being spaced apart along a length of the tape. The tape further includes a magnetic signal written over the portion of the tape containing the servo pattern, wherein the magnetic signal and the servo pattern provide electromagnetic modulation to a magnetic read/write head passed over the servo pattern.

In various embodiments, the magnetic data storage tapes may include one servo pattern or a plurality of servo patterns that are spaced apart across a width of the tape. The tapes may include servo patterns in which at least a portion of the magnetic coating in substantially all of each of the plurality of etched regions is removed. Alternatively, each etched region of the plurality of etched regions may be formed by a plurality of stitches in which at least a portion of the magnetic coating is removed. The servo patterns and magnetic signal may provide electromagnetic modulation that is at least about 10% or higher, more preferably at least about 25% or higher, and even more preferably at least about 50% or higher.

In another aspect, the present invention provides a method of manufacturing magnetic data storage tape by providing a substrate with a magnetic coating on at least one surface and etching a servo pattern in the magnetic coating on the tape. The servo pattern includes a plurality of etched regions in the magnetic coating on the tape, the plurality of etched regions being

spaced apart along a length of the tape. The method further includes magnetically writing over the portion of the tape containing the servo pattern, wherein the magnetic signal and the etched servo pattern provide electromagnetic modulation to a magnetic read/write head passed over the servo pattern.

In other embodiments, the methods of the present may include forming a plurality of servo patterns in the magnetic coating, the plurality of servo patterns being spaced apart across a width of the tape. The plurality of servo patterns may be formed simultaneously or sequentially. Formation of the servo pattern may also include removing at least a portion of the magnetic coating in substantially all of each of the plurality of etched regions. Alternatively, the etched regions may be formed from a plurality of stitches, wherein at least a portion of the magnetic coating in each of the stitches is removed. The servo patterns and magnetization may provide electromagnetic modulation that is at least about 10% or higher, more preferably at least about 25% or higher, and even more preferably at least about 50% or higher. Furthermore, the magnetic writing may be performed before or after the formation of the servo pattern.

In yet another aspect, the present invention provides a method of servo positioning on a magnetic data storage tape including a magnetic coating on at least one surface of a substrate, a servo pattern comprising a plurality of etched regions in the magnetic coating on the tape, the plurality of etched regions being spaced apart along a length of the tape; and a magnetic signal written over the servo pattern. The method includes detecting electromagnetic modulation in the magnetic coating by passing a magnetic core over the servo pattern and detecting optical modulation by passing an optical read head over the servo pattern. A magnetic read/write head is then positioned based on the electromagnetic and optical modulation detected.

In various embodiments, the electromagnetic modulation and the optical modulation can be detected simultaneously or sequentially. The electromagnetic modulation and the optical modulation may be detected using the same servo pattern or they may be detected using different servo patterns.

These and other features and advantages of the present invention are described more completely below in connection with the illustrated embodiments presented.

Brief Description of the Drawings

Figure 1 is a perspective view of a magnetic data storage tape including a plurality of etched servo patterns formed thereon.

Figure 2 is an enlarged plan view of one etched region of a servo pattern.

Figure 3 is a cross-sectional view of the etched region of Figure 2 taken along line 3-3 in Figure 2.

Figure 3A is an enlarged partial cross-sectional view of one etched magnetic data storage tape.

Figure 4 illustrates one method of providing a servo track on magnetic data storage tape according to the present invention.

Figure 5 illustrates a method of providing a plurality of servo tracks on magnetic data storage tape according to the present invention.

Figure 6 illustrates a method of providing servo tracks on two magnetic data storage tapes according to the present invention.

Detailed Description of Illustrative Embodiments of the Invention

The present invention provides magnetic data storage tape with one or more etched servo patterns formed thereon. Figure 1 illustrates one magnetic data storage tape 10 according to the present invention. The tape 10 includes a substrate 12 with a magnetic coating 20 on at least one surface of the substrate 12. The substrate 12 may be formed of any suitable material as will be known to those skilled in the art. The magnetic coating 20 may also be any suitable magnetic coating used in magnetic data storage tapes.

Also, it should be understood that although the magnetic coating 20 and substrate 12 are illustrated as homogenous layers, one or both of the magnetic coating 20 and substrate 12 could be provided as composites of multiple layers of the same or different materials. For example, the substrate 12 may include a base layer of, e.g., polyester, coated with non-magnetic materials on one or both sides. Such a composite is considered to be included within the term "substrate" as used in connection with the present invention. Furthermore, multiple magnetic coatings could be provided on the substrate, with at least some of the magnetic coatings being separated by non-magnetic layers. In addition, the substrate could be provided with magnetic coatings on both of its major sides. Other variations in the exact construction of the media used in connection with the present invention will be known to those skilled in the art of magnetic data storage.

The tape 10 includes two servo patterns *a*, *b* formed in the magnetic coating 20 on the substrate 12. Each of the servo patterns *a*, *b* is formed by a plurality of etched regions 22a, 22b (collectively referred to as etched regions 22) that are aligned along the length of the tape 10.

The servo patterns *a*, *b* are preferably spaced apart across the width of the tape 10, with the area between the servo patterns *a*, *b* being used for data storage. Although the servo patterns are illustrated as being etched into the magnetic coating 20, it will be understood that they could alternatively, be formed in the substrate 12.

Also, although the illustrated patterns are one example of a dedicated servo pattern, it will be understood that the present invention could be implemented in any suitable servo system, e.g., embedded servo patterns, etc. Furthermore, although the illustrated pattern is uniformly repeating along the length of the tape, it will be understood that the pattern or patterns formed according to the present invention could vary along the length of the tape and/or transverse to the length of the tape. In addition, the present invention can be used in connection with boundary servo systems or timing based servo systems.

The servo patterns *a*, *b* may be read optically, magnetically or both optically and magnetically. If the servo patterns *a*, *b* are to be read optically, they may be formed on any appropriate surface of the tape 10. For example, the servo patterns *a*, *b* may be formed in a magnetic coating 20 on the tape 10, or they may be formed on another surface, e.g., in the substrate 12. Alternatively, the servo patterns *a*, *b* may be formed in another coating provided on the tape10 that is selected for its ability to provide an optical servo track with enhanced contrast (e.g., a material that provides high contrast). Wherever formed, the servo patterns to be read optically must exhibit sufficient optical modulation when read by an optical read head to provide accurate positioning information.

Servo patterns *a*, *b* that are to be read magnetically must be formed in a magnetic coating that is magnetized using a magnetic signal such that the servo patterns can be magnetically read. For example, the servo patterns may be overwritten with a magnetic signal in the form of magnetic tone, a constant magnetic field, etc. If the servo patterns *a*, *b* formed in the magnetic coating 20 on the tape 10 are magnetically overwritten, then the servo patterns *a*, *b* on the tape 10 and magnetization combine to form servo tracks that provide electromagnetic modulation when read by a magnetic core. The electromagnetic modulation provided by the servo tracks can then be used to provide the desired servo information needed to accurately position the read/write heads during data storage and retrieval.

In those systems in which the servo positioning will be accomplished by a combination of magnetic and optical servo patterns, the same servo pattern may be used to position both magnetically and optically, provided that the servo

pattern provides both sufficient electromagnetic and optical modulation. Alternatively, different servo patterns could be used to provide the desired electromagnetic and optical modulation. For example, servo pattern *a* could be used to provide electromagnetic modulation to a magnetic core while servo pattern *b* could be used to provide optical modulation. The different patterns could be read simultaneously, sequentially or a combination of simultaneously and sequentially.

The electromagnetic modulation in the servo tracks is caused by the alternating regions 22, in which at least portion of the magnetic coating 20 is removed, and the unaffected magnetic coating 20 between regions 22 along the length of each of the servo patterns *a*, *b*. The unaffected magnetic coating 20 retains the magnetization to a greater degree than the etched regions 22 because at least a portion of the magnetic coating 20 in each etched region 22 has been removed, thereby reducing the ability of the tape 10 to retain magnetization by reducing the magnetic moment Alternatively, the etched regions can provide electromagnetic modulation by increasing separation distance between the magnetic core and the magnetic coating as compared to the areas that are not etched.

Although each etched region 22 may be formed as a single etched area, it may be helpful to provide each etched region 22 in the form of a plurality of stitches 24 located within the etched region 22 as illustrated in Figure 2. If all of the magnetic coating 20 is removed within each of the etched regions 22, the ability to control the height of the read/write head above the tape 10 can be adversely affected. By providing the etched regions 22 as a plurality of spaced apart stitches 24, however, the proper height of the read/write head above the tape 10 may be more easily maintained.

Another variation in the amount of the magnetic coating 20 removed within the etched areas 22 is illustrated in Figure 3, which is a cross-sectional view of Figure 2 taken along line 3-3 in Figure 2. The additional variable illustrated in Figure 3 is the depth to which the magnetic coating 20 is removed from the tape 10. As illustrated in Figure 3, it may be preferred that a portion of the magnetic coating 20 between each stitch 24 and the substrate 12 remain after etching.

Figure 3A illustrates another alternative tape construction in which substantially all of the magnetic coating 20' in each stitch 24' is removed from the tape 10'. The tape 10' also includes an intermediate layer 14' between the magnetic coating 20' and substrate 12' that can be selected to enhance removal of

the magnetic coating 20'. For example, the intermediate layer 14' may be selected for its optical properties (e.g., reflection, absorption, etc.) when the etching is performed using laser energy.

Figure 3A also illustrates an etched region 22' formed in the substrate 12' on the opposite side of the magnetic coating 20'. The etched region 22' could be used in connection with an optical servo pattern as discussed above.

Regardless of the actual form of each etched region in the servo patterns, one important function of the etched regions is to reduce the magnetic properties of selected areas on the tape to provide electromagnetic modulation after signal overwriting. That signal modulation should be significant enough to be accurately detected by a magnetic core. As a result, the exact dimensions of and spacing between the etched regions can vary based on a number of factors including, but not limited to: the properties of the magnetic coating on the substrate, the properties of the core on the read heads, etc.

It may be preferred that the etched regions provide enough deformation or destruction in the magnetic coating on the tape such that electromagnetic modulation of at least about 10% or higher in magnetization written over the servo patterns *a*, *b* is obtained when read back by a magnetic core. More preferably, the modulation provided by the servo tracks is at least about 25% or higher, and even more preferably the modulation is at least about 50% or higher.

The formation of the etched regions on the magnetic data storage tape is preferably accomplished by providing a magnetic data storage tape including a substantially continuous magnetic coating on a substrate. The tape is then processed to form the etched regions in a pattern that can be read optically or magnetically. The etching is preferably performed by laser ablation, although any suitable technique for selectively removing at least a portion of the magnetic coating can be used in place of or in connection with laser ablation. The etched regions can alternatively be formed by, e.g., contact lithography, chemical etching, etc.

Figure 4 illustrates one system for providing a servo tracks on magnetic data storage tape. The system includes a source 30 of laser energy that provides a focused beam 32 of laser energy directed at the tape 10. The tape 10 is preferably moved relative to the beam 32 which is modulated to produce the desired servo pattern of spaced-apart etched regions needed to form a servo track on the tape 10. Those skilled in the art of laser ablation processing will understand that some method of debris removal will also be used to control the debris generated by the

preferred ablation process. For example, a frozen carbon dioxide cleaning system and/or vacuum may be used to control debris removal.

Also illustrated in Figure 4 is a magnetic write head 40 used to magnetize at least the area of the servo track or tracks formed on the tape 10. The magnetization may be performed before or after the etching is completed, although it preferably is performed after etching as illustrated in Figure 4. It will be understood that, although illustrated as being performed in-line with the etching, the magnetization may be accomplished in a separate process that is not performed in-line with etching.

Another variation in the methods of producing an etched magnetic data storage tape 110 is illustrated in Figure 5. This variation involves the simultaneous formation of a plurality of etched servo track patterns on a tape 110. To do so in, e.g., a process using laser energy to etch the magnetic coating on the tape 110, a plurality of the laser beams 132a and 132b may be directed at the tape 110. The beams 132a and 132b may come from a single laser in which the output beam is divided, or the beams 132a and 132b may come from different lasers.

Yet another variation is illustrated in Figure 6, in which servo patterns are simultaneously etched into a plurality of magnetic data storage tapes 210a and 210b using etching beams 232a and 232b. The etching beams 232a and 232b may come from a single laser in which the output beam is divided, or the beams 232a and 232b may come from different lasers.

Systems and methods for the simultaneous etching of a plurality of servo tracks on one magnetic data storage tape or on a plurality of tapes are described in commonly assigned, copending U.S. Patent Application Serial No. 09/251,774, filed February 17, 1999, entitled "Multibeam Laser Servowriting of Magnetic Data Storage Media."

What is claimed is:

1. A magnetic data storage tape comprising:

a magnetic coating on at least one surface of a substrate;

a servo pattern comprising a plurality of etched regions in the magnetic coating on the tape, the plurality of etched regions being spaced apart along a length of the tape; and

a magnetic signal written over the servo pattern, wherein the magnetic signal and the servo pattern provide electromagnetic modulation to a magnetic core passed over the servo pattern.

2. The tape of claim 1, wherein a plurality of servo patterns are formed in the tape, the plurality of servo patterns being spaced apart across a width of the tape.

3. The tape of claim 1, wherein at least a portion of the magnetic coating in substantially all of each of the plurality of etched regions is removed.

4. The tape of claim 1, wherein each etched region of the plurality of etched regions comprises a plurality of stitches in which at least a portion of the magnetic coating is removed.

5. The tape of claim 1, wherein the electromagnetic modulation is at least about 25% or higher.

6. The tape of claim 1, further comprising an intermediate layer between the magnetic coating and the substrate, the intermediate layer exhibiting at least one selected optical property.

7. A method of manufacturing magnetic data storage tape comprising:

providing a substrate with a magnetic coating on at least one surface;

etching a servo pattern in the magnetic coating on the tape, the servo pattern comprising a plurality of etched regions, the plurality of etched regions being spaced apart along a length of the tape; and

writing a magnetic signal over the servo pattern, wherein the magnetic signal and the servo pattern provide electromagnetic modulation to a magnetic core passed over the servo pattern.

8. The method of claim 7, further comprising forming a plurality of servo patterns in the tape, the plurality of servo patterns being spaced apart across a width of the tape.

9. The method of claim 8, wherein the plurality of servo patterns are formed simultaneously.

10. The method of claim 8, wherein the plurality of servo patterns are formed sequentially.

11. The method of claim 7, wherein forming the servo pattern further comprises forming a plurality of stitches each of the etched regions, wherein at least a portion of the magnetic coating in each of the stitches is removed.

12. The method of claim 9, wherein the electromagnetic modulation is at least about 50% or higher.

13. The method of claim 9, wherein the magnetic signal is written on the tape after the servo pattern is formed.

14. The method of claim 9, wherein the magnetic signal is written on the tape before the servo pattern is formed.

15. A method of servo positioning on a magnetic data storage tape comprising:

providing a magnetic data storage tape comprising a magnetic coating on at least one surface of a substrate, a servo pattern comprising a plurality of etched regions in the magnetic coating on the tape, the plurality of etched regions being spaced apart along a length of the tape; and a magnetic signal written over the servo pattern;

detecting electromagnetic modulation in the magnetic coating by passing a magnetic core over the servo pattern;

detecting optical modulation by passing an optical read head over the servo pattern; and

positioning a magnetic read/write head based on the electromagnetic modulation and the optical modulation.

16. The method of claim 15, wherein the electromagnetic modulation and the optical modulation are detected simultaneously.

17. The method of claim 15, wherein the electromagnetic modulation and the optical modulation are detected sequentially.

18. The method of claim 15, wherein the electromagnetic modulation and the optical modulation are detected using the same servo pattern.

19. The method of claim 15, wherein the tape comprises a plurality of servo patterns, and further wherein the electromagnetic modulation and the optical modulation are detected using different servo patterns.

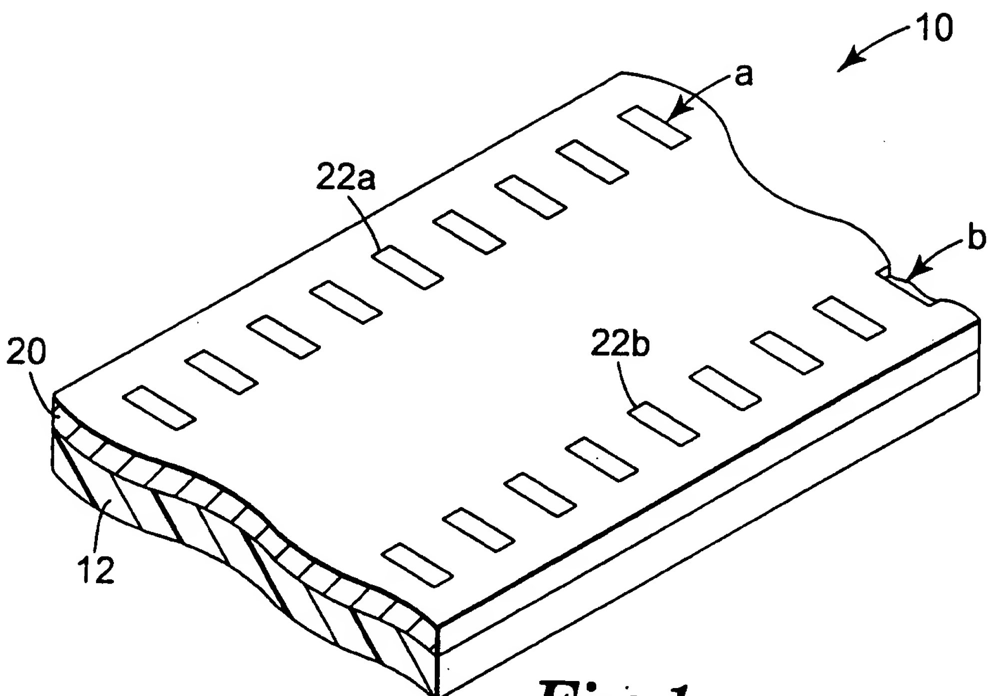

Fig.1

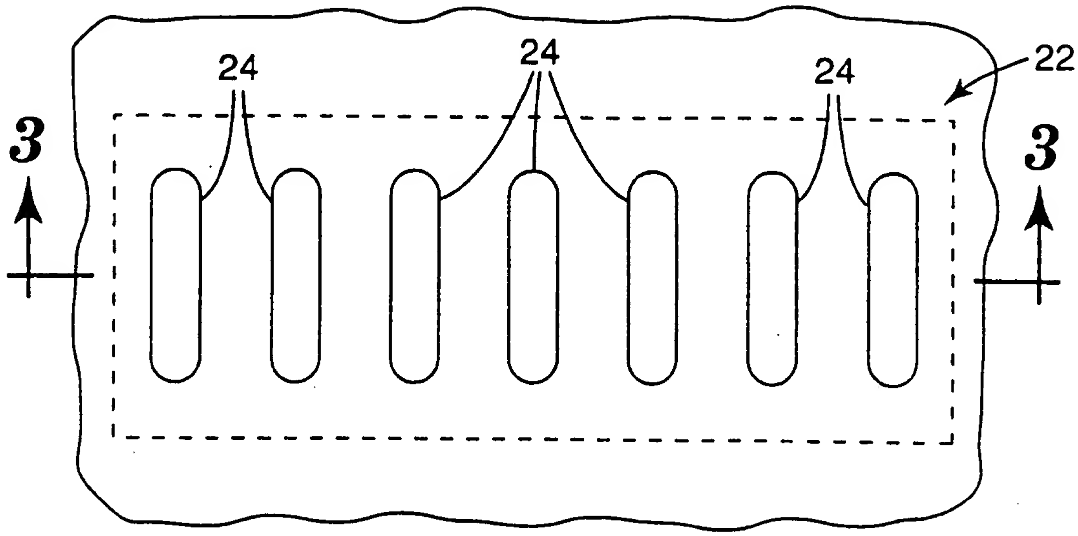

Fig. 2

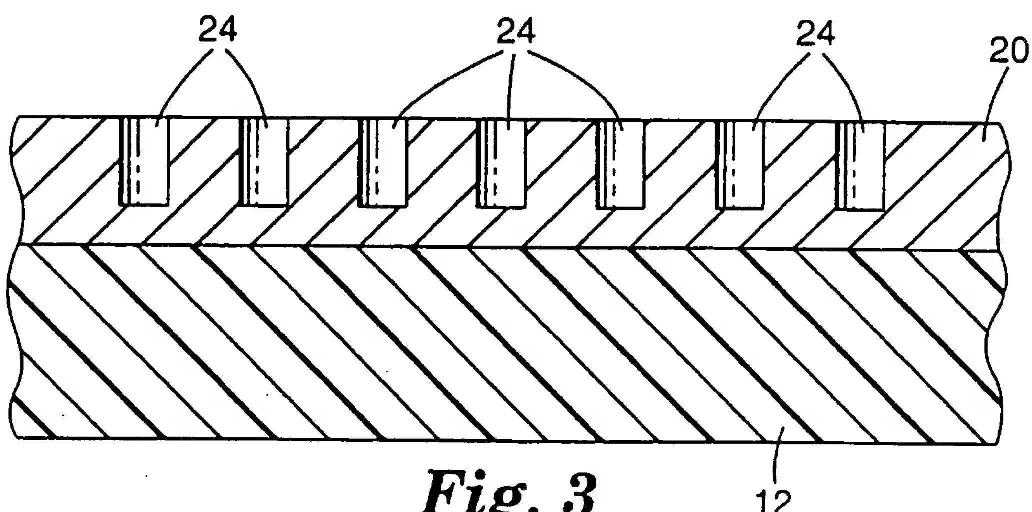

Fig. 3

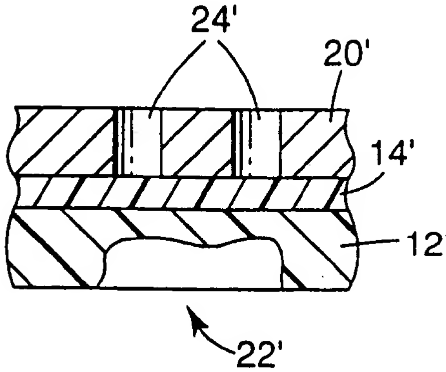

Fig. 3A

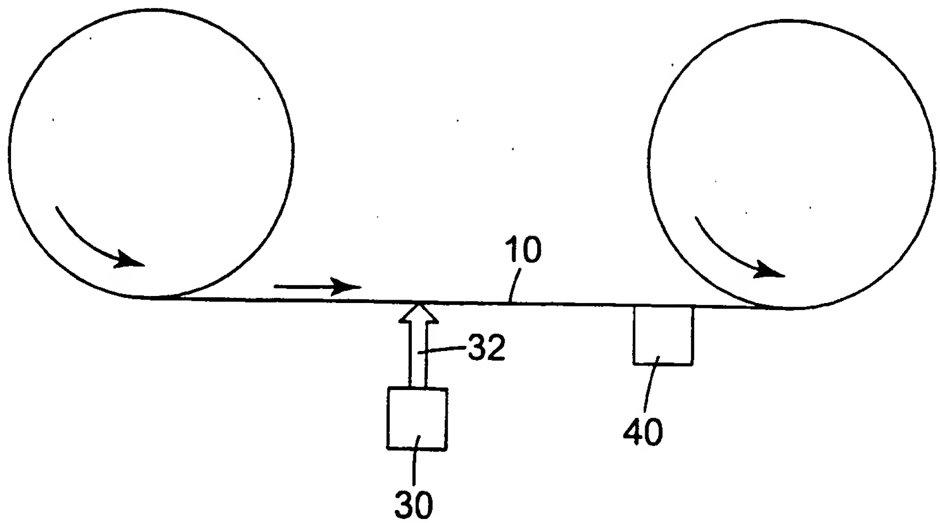

Fig. 4

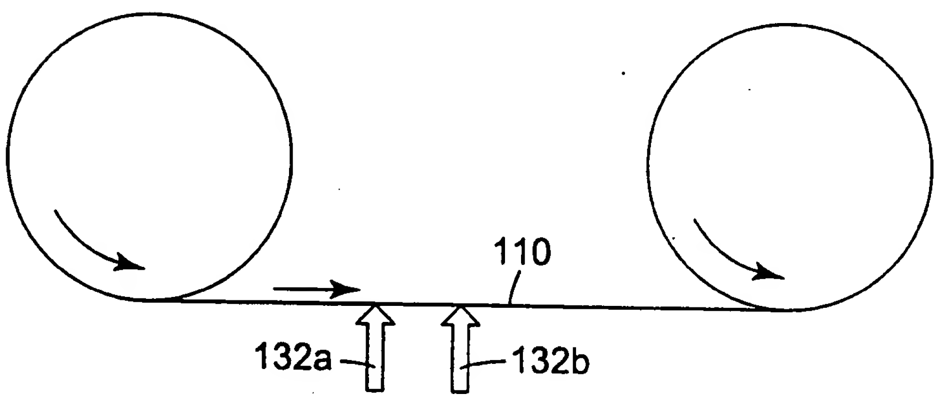

Fig. 5

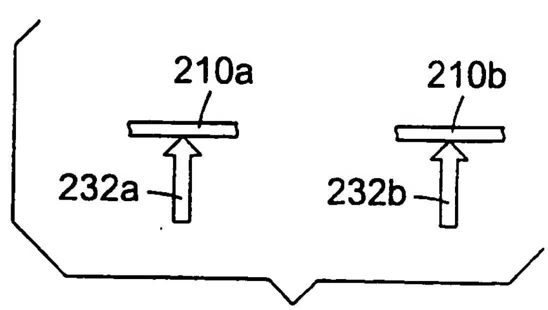

Fig. 6

B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

APS Text: laser, etch? optic? servo track? Gas, alignment, pin, pressure? Gas

APS Image

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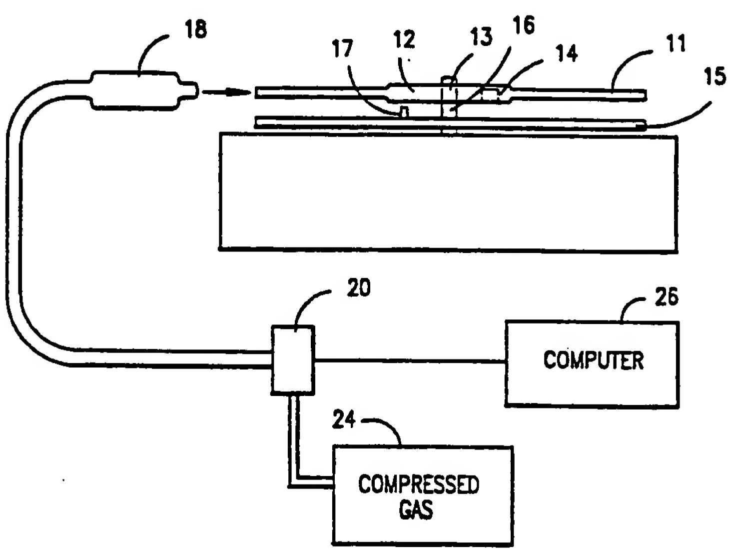
(54) Title: PNEUMATIC HUB LOCKING DEVICE FOR ETCHING OPTICAL SERVO TRACKS ON MAGNETIC DISKS



(57) Abstract

An apparatus for etching optical servo tracks on a magnetic storage disk (11) comprises optics for generating a beam of light for etching the servo tracks and a spindle (15) for rotating the disk (11) in proximity to the optics. The device further comprises a center pin (16) at the center of rotation of the spindle and an alignment pin (17) which is off-center of the spindle (15). A disk (11) to be etched is placed on the spindle (15) with the center pin (16) through a center hole (13) in the disk hub (12). A pressurized gas nozzle (18) directs bursts of pressurized gas toward the edge of the disk (11) to rotate the disk (11) until an alignment hole (14) in the disk hub (12) engages the alignment pin (17).

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PNEUMATIC HUB LOCKING DEVICE FOR ETCHING OPTICAL SERVO TRACKS ON MAGNETIC DISKS

Field of the Invention

This invention relates to etching optical servo tracks on magnetic disks and more particularly to an automatic hub locking device for accurately positioning the magnetic disk on which servo tracks are to be etched.

Related Applications

Steering Laser Beam While Etching Optical Servo Tracks for Magnetic Disks, Serial No. 07/896,188, filed June 10, 1992; Apparatus for and Method of Verifying Etching of Optical Servo Information on Magnetic Media, Serial No. 07/896,197, filed June 10, 1992; and Acousto-Optical Intensity Control of Laser Beam During Etching of Optical Servo Information On Magnetic Media, Serial No. 07/896,196, filed June 10, 1992. The foregoing applications show the etching system to which the present invention relates.

Background of the Invention

So-called "floppy" disk memory systems for "desk top" sized computers are well known in the art. Such systems employ magnetic storage disks having a diameter of either 5.25 inches or 3.50 inches. Conventional magnetic storage disks for floppy disk drives have a track density ranging from forty-eight (48) to one hundred thirty-five (135) tracks per inch (TPI). In contrast, optical storage disks for optical memory systems achieve track densities greater than 15,000 TPI. The greater track density of optical disks is

achieved by th use f optical servos that maintain fine positioning of the optical read\write head over the data tracks on the disk. Typically, concentric optical servo tracks are pre-recorded on the optical disk to guide the servo mechanism.

New advances in barium-ferrite magnetic media have allowed bit densities of magnetic storage disks to exceed the bit densities of optical disks. However, as mentioned above, track densities of magnetic media (48 - 135 TPI) are many times less than their optical counterparts. This limits the overall capacity of magnetic disks as compared to optical disks. Conventional magnetic disk systems employ a magnetic servo mechanism and magnetically pre-recorded servo tracks on the disks to guide the read\write head. Magnetic servo systems cannot provide the fine positioning that optical servo systems can provide.

Recently, floppy disk systems have been developed that combine magnetic disk recording techniques with the high track capacity optical servos found in optical disk systems. Such a system is described in AN INTRODUCTION TO THE INSITE 325 FLOPTICAL(R) DISK DRIVE, Godwin, in a paper presented at the SPIE Optical Data Storage Topical Meeting (1989). Essentially, an optical servo pattern is pre-recorded on a magnetic floppy disk. The optical servo pattern typically consists of a large number of equally spaced concentric tracks about the rotational axis of the disk. Data is stored in the magnetic "tracks" between the optical servo tracks using conventional magnetic recording techniques. An optical servo mechanism is provided to guide the magnetic read\write head accurately over the data between the optical servo tracks. By utilizing optical servo techniques, much higher track densities are achievable on the relatively inexpensive removable magnetic medium.

As mentioned, the optical servo pattern typically consists of a large number of equally spaced concentric tracks about the rotational axis of the disk. As disclosed in U.S. Patent No. 4,961,123, each track may be a single

continuous groove (Fig. 3), a plurality of equally spaced circular pits (Fig. 8), or a plurality of short equally spaced grooves or stitches (Fig. 9). Various methods and systems exist for inscribing the optical servo tracks on the magnetic medium.

For example, U.S. Patent No. 5,067,039, entitled "High Track Density Magnetic Media with Pitted Optical Servo Tracks and Method for Stamping the Tracks on the Media," discloses a method for "stamping" the servo tracks on the magnetic medium. Essentially a master stamping disk is produced bearing a template of the optical servo pattern. This master disk is then pressed against the magnetic floppy disk under a pressure of several tons per square inch. The significant amount of pressure transfers the servo track pattern from the master disk to the floppy.

U.S. Patent No. 4,633,451, entitled "Optical Servo for Magnetic Disks," discloses a method of providing optical servo information on a magnetic medium consisting of a multi-layer film. The optical servo tracks are formed on the multi-layer film by laser heating the structure to cause a reaction or interdiffusion to occur between layers. The reaction produces a reflectivity contrast of about eight percent (8%) between exposed and unexposed areas. Other methods for preparing the servo tracks are mentioned including contact printing, embossing, and lithography.

U.S. Patent No. 4,961,123, entitled "Magnetic Information Media Storage with Optical Servo Tracks," discloses a preferable method and apparatus for etching the pattern on a disk using a focused beam of light. The magnetic disk is placed on a platen/spindle assembly and rotated. A beam of light is focused to a small spot on the spinning disk. The focussed beam has sufficient intensity to ablate the disk surface at the point of incidence, thereby reducing the reflectivity of the surface at that point. The beam can be left on during an entire revolution to produce a continuous groove or can be modulated on and off through one revolution to produce a stitched pattern. This method has

several advantages. First, the intensity of the f cussed beam of light can be adjusted for different types of magnetic media. Secondly, different stitched patterns can be etched simply by varying the on-off time of the beam or by varying the speed of rotation of the disk. Additionally, there is no need to produce a master disk, as with the stamping method.

As mentioned above, the optical servo pattern often comprises a number of equally spaced concentric optical servo tracks about the rotational axis of the disk. A single disk may have as many as 900 concentric servo tracks. Additionally, each optical servo track may be a continuous groove, or alternatively, may comprise a plurality of equally spaced stitches. When a stitched pattern is employed, the number of stitches in each optical servo track may exceed 1600 with each track having the same number of stitches. It is crucial for proper servo positioning that every stitch be sufficiently detectable by the servo optics. As mentioned, a preferred method of producing a stitched pattern is by focusing a beam of light on a rotating disk and modulating the beam on and off. The beam, when incident upon the surface of the disk and properly focused, has sufficient intensity to etch the surface thereby creating a stitch having reduced reflectivity.

Magnetic disks of this type are engaged and centered in disk drives by a stamped, metal central hub to which the disk is attached with adhesive. This hub has a center rectangular hole through which the center pin is engaged and a skewered rectang-ular hole off of the disk center through which an alignment pin fits. During the etching of the servo tracks, it is necessary that the magnetic disk be correctly aligned with respect to these holes, so that the servo tracks will be laid down accurately for proper optical reading during operation of the disk drive.

Summary f the Inventi n

In accordance with the present inventi n, the magnetic disk on which optical servo tracks are to be etched is automat-ically positioned on a spindle by a pressurized source of gas which rotates the disk until an alignment pin engages an alignment hole in the disk and until a corner of the disk center hole is correctly positioned against the center pin.

The center pin is longer than the alignment pin so that the disk can be placed on the center pin without having to align the alignment pin with the disk hub alignment hole. The air pressure system of this invention rotates the disk until the hub alignment hole engages with the alignment pin. This increases the speed of the disk hubbing operation.

In accordance with the present invention, the gas (air) nozzle is placed at the appropriate angle and location relative to the edge of the media to provide a torquing force for the disk. The pressurized air also lifts the disk slightly off the spindle to provide a gas boundry layer while rotating the disk. This protects the media from scratching while being positioned.

In accordance with another embodiment of the present invention, a second gas nozzle is added. The pressurized gas from the second nozzle provides additional torque to rotate the disk. The second nozzle also adds stability.

A small magnet ring is positioned on the spindle below the steel hub of the disk. The magnet provides a slight disk retaining force while the disk is being torqued into the hub locked position.

Further in accordance with the invention, a low-friction outer ring on the spindle allows the outer edge of the disk hub to slide freely while it is being rotated.

Further in accordance with the invention, alignment scales are provided for aligning the laser beam.

The foregoing and further objects, features and advantages of the invention will be better understood fr m the following more detailed description and appended claims.

Short Description of the Drawings

Figure 1 is a front view of the spindle and pressurized source of air of the present invention;

Figure 1A is a top view of the spindle of Figure 1;

Figure 1B shows the magnetic disk and its hub;

Figure 1C shows a magnetic disk mounted on the spindle of Figure 1;

Figure 2 is a front view of an alternate embodiment of the present invention with two pressurized sources of air;

Figure 2A is a top view of the alternate embodiment shown in Figure 2;

Figure 3 is a block diagram of the apparatus for etching optical servo information on magnetic disks.

Figure 4 shows the optical bench layout; and

Figures 5, 5A and 5B show the alignment scales and holders.

Figure 6 is a block diagram showing further details of the acousto-optical device of Figure 3.

Description of the Preferred Embodiment

Figure 1B depicts the magnetic disk on which optical servo tracks are to be etched. Disk 11 has a stamped metal central hub 12 to which the disk is attached with adhesive. Two holes are punched in the hub. A square (rectangular) center hole 13 engages the center pin of the magnetic disk drive. A larger skewed rectangular alignment hole 14 engages a second pin of the disk drive. The pin through the skewed alignment hole engages an edge of this hole to torque the hub so that the center pin of the disk drive engages in the same corner of the center hole 13 each time. The corner provides a reference point relative to the center of rotation of the disk. This engagement of drive center pin to a hub center hole corner is the mechanism for

rep atable and accurate centering of the disk in the drive. This same centering or hub locking process must be performed each time a disk is loaded onto the spindl of the laser etching system used to produce the laser etched servo tracks.

Figure 1 is a front view of the air bearing spindle upon which the magnetic disk is mounted prior to laser etching of servo groove stitches. The system used to mount and lock the disk to the spindle 15 includes the following features. The spindle 15 includes a disk center pin 16 and an off-center alignment pin 17. The top of center pin 16 is crowned with a smooth radius. The top of the alignment pin 17 is slightly shorter than the crown of center pin 16. This pin configuration allows the operator to place the disk on the center pin 16 of the spindle 15 without having to align the alignment pin 17 with the alignment hole 14.

A pressurized gas nozzle 18 is directed at the edge of the disk. For example, a pressurized air source is used such as a tank of compressed air 24. When a burst of pressurized air is released, the disk placed on the spindle 15 is torqued in a clockwise direction, until the alignment hole 14 in the disk hub 12 engages with the spindle alignment pin 17. Once engaged, the disk is further torqued until the alignment pin 17 rests tightly against the outer edge of the alignment hole 14. This positions the spindle's center pin 16 tightly against the two edges of the hub center hole 13 at the corner 19 (Fig. 1B). With this action, the disk is centered or "hub locked" in a position to be laser etched.

The pressurized air nozzle 18 is placed at the appropriate angle and location relative to the edge of the disk to apply a torquing force to the disk. The pressurized air also lifts the disk slightly off the spindle 15. This produces a gas boundry layer while rotating the disk. This provides the disk with a degree of protection from scratching while it is being positioned.

A solenoid 20 controlled by computer 26 enables the burst of gas to be correctly directed to torque and lock the hub 12 of the disk into position. The computer controlled

burst of air provides positive media hub locking until the rotation speed f the spindle 15 is high enough so that the spindle's positon retention system is able to retain the hub locked disk in position.

Referring now to Figure 1A, a top view of the apparatus is shown which illustrates further details of the apparatus. A small magnetic ring 21 is on the spindle 15 just below where the steel hub of the disk rests when it is placed on the spindle 15. The magnet 21 provides a slight disk retaining force while the disk is being torqued into the hub locked position. This provides an addeded margin of reliability to the operation. A low-friction bearing ring 22 of teflon is under the disk hub 12. The bearing ring 22 is at the outer edge of the center circular counterboard area of spindle 15. The lowest physical plane on the side of the disk resting on the spindle 15 is located on the outer radius or edge of the disk hub 12. This plane slides freely on the teflon bearing ring 22 while the hub 12 is rotated into the hub locked position.

A spindle retention system, like that used in the aforementioned Insite system, comprises a series of radial cut troughs 28 in the spindle surface upon which the disk rests. As the rotational speed of the spindle increases, an airflow is generated from the center of the spindle through these troughs. This airflow in turn creates a downward suction force on the disk due to a drop in static pressure in these troughs. This downward force retains the disk in the hub lock position for the duration of the etching cycle.

Figure 1C shows the disk 11 mounted on the spindle 15. In the figure, the alignment pin 17 has not yet engaged the alignment hole 14 in the disk hub 12. A burst of pressurized air from the nozzle 18 will torque the disk in a clockwise direction, until the alignment hole 14 in the disk hub 12 engages with the spindle alignment pin 17. As described above, once engaged, the disk 11 is further torqued until the alignment pin 17 rests tightly against th outer edge of the alignment hole 14.

Figure 2 is a front view of an alternate embodiment of the present invention. In the alternate embodiment, th nozzle 18 defines a first nozzle, and the apparatus further comprises a second nozzle 30. The second nozzle 30 operates substantially simultaneously with the first nozzle and provides further torque to the disk. The second nozzle 30 also acts to equalize the torque on the disk. Figure 2A best shows the preferred positioning of the second nozzle 30 relative to the spindle 15 and the first nozzle 18.

Figure 3 shows a preferred embodiment of the complete apparatus for etching the magnetic disk. The apparatus includes a light source 40 for etching a plurality of concentric optical servo tracks about the rotational axis of a magnetic storage disc wherein each track comprises a plurality of equally spaced etched stitches.

Light source 40 provides a collimated incident beam of light 42. The light source 40 has means (not shown) for linearly polarizing the incident beam of light in a first polarizing direction. The direction of linear polarization, i.e., the first polarizing direction, is not critical. In the preferred embodiment, the light source 40 is a laser tuned to a wavelength suitable for etching the surface of the magnetic medium. Thus, the incident beam is highly collimated and monochromatic. Different wavelengths may be used with magnetic media having different characteristics. Two brewster windows (not shown) in the laser tube comprise the means for linearly polarizing the incident beam.

An acousto-optical device 44 adjusts the intensity of the incident beam and steers the beam for reasons which will become evident hereinafter. Acousto-optical devices are described generally in Wilson & Hawkes, OPTOELECTRONICS: AN INTRODUCTION, pp. 111 to 116 (Prentice/Hall 1983). The Acousto-optical (AO) device 44 is described hereinafter in greater detail. Briefly, the AO device 44 accepts digital frequency data at a first input 43 and analog voltage data at a second input 45. The frequency data and voltage data control the frequency and amplitude, respectively, of an

ultrasonic wave applied to a birefringent crystal in the device 44 which changes the index of refraction of the crystal in ne direction. Changes in the frequency of the ultrasonic wave produce deflections of the incident beam as it travels through the crystal. Changes in the amplitude of the ultrasonic wave create corresponding changes in the intensity of the beam.

Mirror 50 directs the linearly polarized incident beam through a beam separator 52. Beam separator 52 has means for transmitting light linearly polarized in the first polarizing direction (as is the incident beam) and for deflecting light linearly polarized in a direction orthogonal to the first polarizing direction. In the preferred embodiment, the means for transmitting light linearly polarized in the first polarizing direction and for deflecting light polarized orthogonal thereto is a multilayer dielectric thin film laser line coating 53 positioned along the hypotenuse of the beam separator 52.

The beam separator 52 transmits the linearly polarized incident beam and mirrors 51, 55 direct the transmitted incident beam to an objective lens 54. The lens 54 focuses the incident beam to a point 57 on a magnetic storage disk 61 to be etched. A platen/spindle assembly 59, which includes the features of the present invention described in conjunction with Figures 1 and 2, rotates the disk 61 about its rotational axis. The lens 54 is positioned such that the rotating disc lies substantially in the focal plane of the lens 54. The focused incident beam reacts with the rotating magnetic medium 61 at the point 57 to create a stitch (not shown) on the medium 61 having reduced reflectivity. A portion of the focused incident beam is reflected. Since the incident beam is focused to a fine point on the magnetic medium, the reflected light effectively emanates from a point source. As described above, the rotating disk 61 lies in the focal plane of the lens, and therefore, the point source of reflected light lies at the focal point of the first lens 54. Consequently, the lens 54

operates to collimate the reflected light and direct a reflected beam back toward the beam separator 52 via th mirrors 51,55. The reflected beam is used for etch verification as is more fully described in co-pending U.S. patent application, Serial No. 07/896,197, filed June 10, 1992, entitled "Apparatus for and Method of Verifying Etching of Optical Servo Information on Magnetic Media."

A voice coil actuator 72 moves the optics 71 which generate the beam of light so that the beam moves radially of the disk for etching each of the concentric servo tracks. In the preferred embodiment, the beam of light is moved continuously radially of the disk 61. The actuator 72 is moved by a closed loop positioning system which comprises up/down count generator 75, counter 76, digital-to-analog converter 77 and laser Doppler meter 79. To initiate movement, microprocessor 81 loads a value into the up/down count generator 75. The up/down count generator 75 produces a pulse train having a given number of pulses at a given velocity for indicating desired position. These pulses increment or decrement the counter 76 depending upon the desired direction of movement. The output of the counter 76 drives the digital-to-analog converter 77 which generates an error voltage. An amplifier 78 provides compensation and current amplification. Amplifier 78 causes current to flow in the voice coil actuator 72, causing the actuator 72 to move in the desired direction. This movement is detected by the laser Doppler meter 79, which feeds back the new position. This signal causes the counter 76 to increment or decrement back to the zero position.

In the preferred embodiment, the incident beam is moved continuously radially of the disk 61. Because the optics 71 which generate the incident beam are continuously moving radially of the disk, the acousto-optical device 44 is used to steer the incident beam in order to maintain the beam in the concentrical pattern of the track being etched.

The radial position of the optics 71 during the etching of a given servo track (i.e., an etch cycle) is

encoded by the laser Doppler meter 79. A bi-directional laser beam 65 that strikes a retro-reflector 63 on the ptics 71 provides positioning information to the laser Doppler meter 79. The resolution of the laser Doppler meter 79 is adjustable. In the preferred embodiment, the laser Doppler meter 79 is adjusted to discern movement of the optics 71 in increments of 1/516 of the track-to-track distance t_d. As the optics 71 move radially through each 1/516th increment during the etching of a track, the laser Doppler meter 79 increments a track position counter 85. The track position counter 85, therefore, maintains a count which indicates the radial position of the optics 71 during an etch cycle. The counter 85 is reset at the beginning of each etch cycle.

Acousto-optical device 44, which is used to steer the beam, is controlled by sets of digital steering signals retrieved from a first random-access-memory (RAM) 98. Each digital steering signal stored in the first RAM 98 represents the beam angle α required for a particular radial position of the optics 71 during an etch cycle. In the preferred embodiment, there are 516 steering signals stored in the first RAM 98 - one for each of the 516 positions encoded by the laser Doppler meter 79 during an etch cycle. The output of the track position counter 85 provides the memory address of the appropriate stored signal for a given radial position. The acousto-optical device 44 responds to the retrieved steering signals to steer the beam to maintain the beam in the concentrical pattern of the track being etched.

The AO device 44 is controlled by sets of digital intensity signals retrieved from a second random-access-memory (RAM) 90. The sets of digital intensity signals are selected under control of microprocessor 81 and in response to the radial position of the incident beam relative to the disk 61. The digital intensity signals are converted to an analog voltage signal by a digital-to-analog converter (DAC) 92. For purposes described more fully below, the analog voltage signal passes through an analog switch 94 which performs a gating function in response to the output of a

third random-access-memory (RAM) 96. The analog voltage signal then passes fr m switch 94 to th AO device 44. The AO device 44 is responsive to the amplitude of the analog signal from DAC 92 to adjust the intensity of the incident beam transmitted through the device 44.

The digital intensity signals are stored in a table in the second RAM 90 as a function of the radial position of the beam. In addition, because beam steering angle can affect the energy density delivered by the beam, the intensity signals are also a function of beam steering angle. The intensity signals are retrieved and applied to the device 44 using a memory-mapped approach similar to that described above for the steering signals.

Fig. 4 shows the optical bench layout for the system of Fig. 3. Like elements have the same reference numerals as in Fig. 3. The system further comprises a laser shutter 100, mirrors 101 and 102, beam aligner 104, and aperture stop 105. All of the components of the apparatus are mounted on a vibration isolated steel bench 106 which has regularly spaced holes over the entire surface of the bench. Holes are indicated at 107 and 108. The components are positioned on the bench with respect to the regularly spaced index holes.

The laser beam is passed through and reflected off of an assortment of electro-optical and optical components prior to being focused onto the disk. In order to make the system operational, the laser beam must be aligned to these components. The laser beam must be aligned with regard to the angular path of travel in the horizontal and vertical planes. Deviations in these angles translate into changes in beam height above the optical bench 106 and divergence from the beam's paths. In order to provide a repeatable and straightforward method to form this alignment, an alignment scale of this invention is provided. Fig. 5 shows the vertical alignment scale 109 and the horizontal alignment scale 110 in a magnetic holder 111. The magnetic base 111 holds the scales in place after they are positioned on the

steel optical bench surface 106. The scales 109 and 110 are longer than the equally spaced index holes 107, 108 on the optical bench surface. (In the example under c nsideration, the holes are on one inch centers). This allows for accurate placement of the scales on the optical bench surface because the scales are indexed off the hole locations.

Vertical scale 109 is longer than the maximum height above the optical bench 106 which the laser beam is required to travel. Vertical scale 109 is shown in more detail in Fig. 5B. It has a slot 112 which is slightly narrower than the laser beam diameter. This allows the slot to catch and make visible the laser beam. The person aligning the laser beam sees the edges of the beam on the scale. The slot 112 is milled along the vertical axis of the scale and has a length which encompasses all laser beam heights required in the system.

The pair of scales 109 and 110 and their slots define either a plane or an axis of travel for the laser beam which is to be aligned using the various fold mirror pitch and roll adjustments of the optics.

Referring now to Figure 6, the acousto-optical device 44 of Figure 3 is shown in greater detail. The device 44 accepts the 16-bit digital signals retrieved from RAM 98 (Figure 3) at a first input 43. The device 44 accepts the analog voltage signal from switch 94 (Figure 3) at a second input 45. The 16-bit digital signals (i.e., words) are received by control electronics 100 and fed to a digital/direct frequency synthesizer 102. The frequency synthesizer 102 produces a fixed amplitude oscillating signal having a frequency which varies in response to, and proportional to, the digital values of the 16-bit signals from the RAM 98 (Figure e). The oscillating signal is fed to modulator/mixer circuit 104.

The analog voltage signal is received by control electronics 106 which condition the signal and pass the signal to the modulator 104. The amplitude of the analog voltage varies fr m 0 to 1 volts. The modulat r/mixer 104

amplitude modulates the oscillating signal from the synthesizer 102 with the analog voltage signal. The output of modulator/mixer 104 is fed t amplifier 108 which amplifies the signal and feeds it to a transducer 110 which is coupled to a bi-refringent crystal 112. The transducer 110 produces an ultrasonic wave having the same frequency/amplitude characteristics as the electronic signal from the modulator/mixer 104. The ultrasonic wave is applied to the birefringent crystal 112. The incident beam is directed through the crystal 112. The ultrasonic wave changes the index of refraction of the crystal in one direction. The frequency of the ultrasonic wave controls deflection or steering of the incident beam as it travels through the crystal, while the amplitude of the ultrasonic wave controls the intensity of the beam that exits from the crystal.

Thus, as described above, the 16-bit digital signals from RAM 98 (Figure 3) control the steering angle of the incident beam as it passes through the device 44. The analog signal generated by the digital-to-analog converter 92 in response to the digital signals retrieved from RAM 90 controls the intensity of the incident beam.

The device 44 was manufactured by Neos Corp., Melbourne, Fl. Typically, acousto-optical devices use a voltage controlled oscillator (VCO) to control the frequency of the signal fed to the transducer 110. In accordance with the present invention, however, the typically employed VCO was replaced with the digital/direct frequency synthesizer 102. The synthesizer 102 achieves a much higher frequency stability, and therefore beam steering stability, over time and temperature. Such enhanced frequency/steering stability is necessary to achieve the tight stitch width and placement tolerances required in accordance with the present invention.

While a particular embodiment of the invention has been shown and described, various modifications of the invention are within the true spirit and scope of the

invention. The appended claims are, therefore, intended to cover all such modifications.

WHAT IS CLAIMED IS:

1. Apparatus for etching a plurality of optical servo tracks about the rotational axis of a magnetic storage disk in relation to magnetic tracks on said disk, said disk being mounted on a hub having a rectangular center hole for engagement with a magnetic disk drive and an alignment hole spaced radially of the center of said disk hub comprising:

optics for generating a beam of light for etching said optical servo tracks;

a spindle for rotating said disk in proximity to said optics;

a center pin at the center of rotation of said spindle;

an alignment pin which is off-center of said spindle, said alignment pin being shorter than said center pin; and

a pressurized gas nozzle for directing bursts of pressurized gas toward the edge of a disk which is placed on said spindle with said center pin through said center hole, said pressurized gas applying torque to said disk to rotate it until said alignment hole engages said alignment pin.

2. The apparatus recited in claim 1 wherein said pressurized gas nozzle defines a first pressurized gas nozzle and further comprising a second pressurized gas nozzle for directing bursts of pressurized gas toward the edge of the disk, said second nozzle operating substantially simultaneously with said first nozzle, said pressurized gas from said second nozzle applying additional torque to said disk.

3. The apparatus recited in claim 1 wherein said center hole in said disk is rectangular with a corner of said rectangle providing a reference point relative to the center of rotation of said disk and wherein said pressurized gas

positions the disk with the two edges of said said corner against said center pin.

4. The apparatus recited in claim 1 wherein said alignment hole is rectangular and wherein said pressurized gas rotates said disk until said alignment pin abuts the outer radius edge of said alignment hole.

5. The apparatus recited in claim 1 wherein said hub of said disk is of a magnetic material, further comprising:

a magnetic ring on said spindle below said hub, said magnetic ring exerting a retaining force on said hub while said disk is being rotated into a position in which said hub is locked.

6. The apparatus recited in claim 1 further comprising a low friction ring on said spindle, said low friction ring being positioned to contact the edge of the hub of a disk placed on said spindle, so that it may slide freely while being rotated by said air pressure.

7. The apparatus recited in claim 1 wherein said pressurized gas is directed at the edge of said disk to lift the disk off the spindle with a gas boundry layer while said disk is rotated.

8. The apparatus recited in claim 1 wherein the top of said center pin is crowned with a smooth radius.

9. The apparatus recited in claim 1 further comprising:

an optical bench;

means for adjustably mounting said optics on said bench; and

alignment scales positioned on said bench for aligning said beam of light with respect to said spindle by adjusting said optics.

10. The apparatus recited in claim 9 wherein said alignment scales include a vertical scale having marks indicating the height above said bench, said vertical scale being placed in the path of said beam of light so that said optics can be adjusted to place said beam at the proper height.

11. The apparatus recited in claim 10 wherein said vertical scale has a slot which is slightly narrower than the width of said beam of light so that said beam is visible on said scale.

12. The apparatus recited in claim 9 wherein said bench is a vibration isolated steel bench and further comprising:

magnetic holders for said alignment scales so that said scales can be movably positioned on said bench.

13. The apparatus recited in claim 12 wherein said bench has a plurality of index holes for positioning said optics and wherein said alignment scales comprise a horizontal scale for positioning said optics with said last named holes as a reference.

FIG. 1

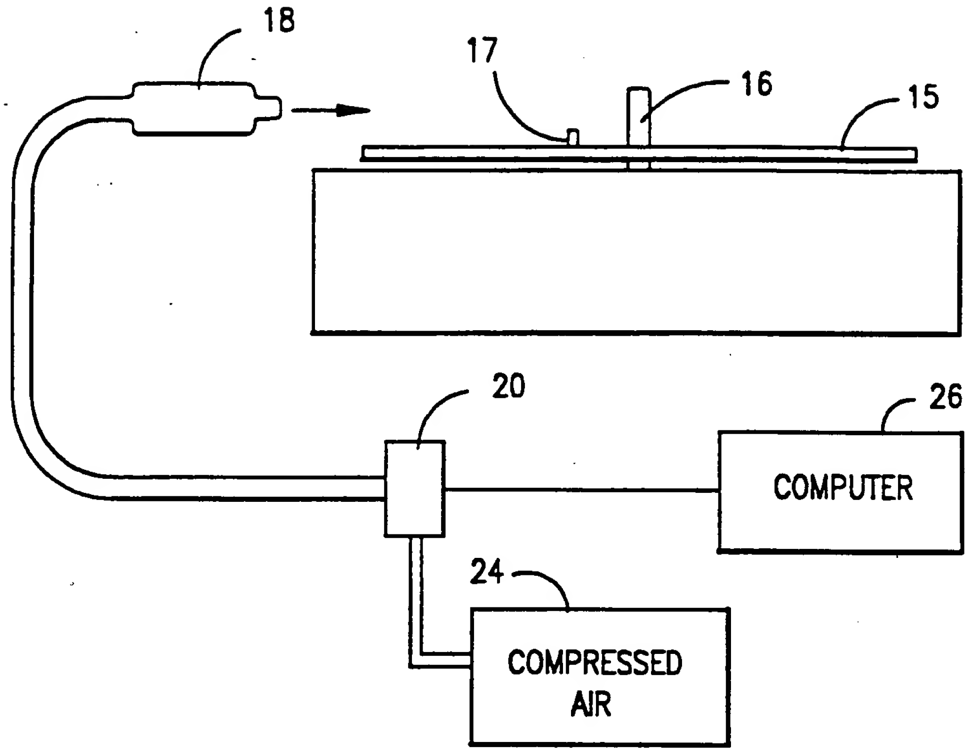


FIG. 1A

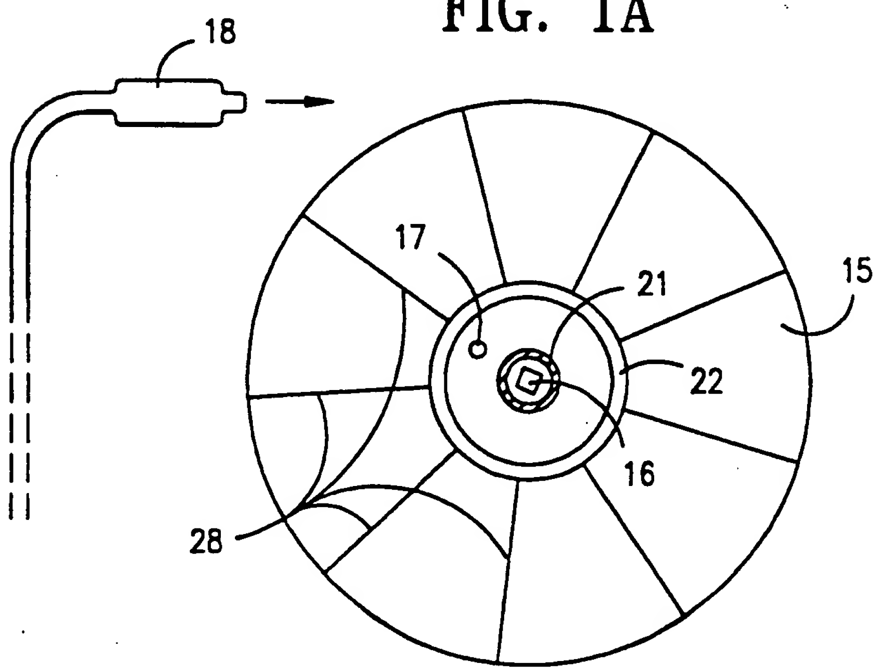


FIG. 1B

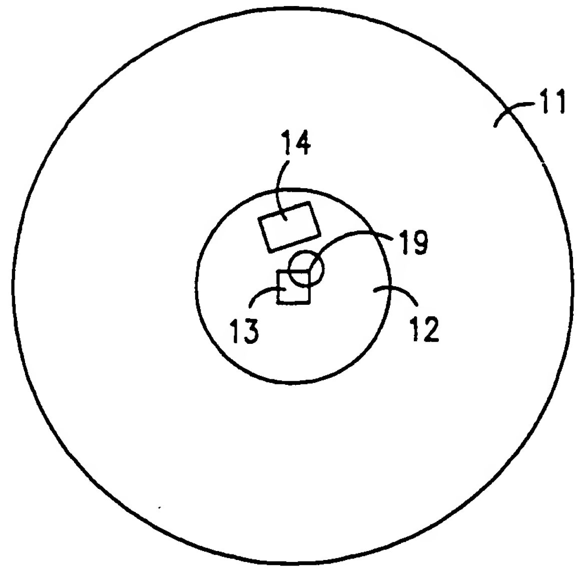

11
14
19
13
12

FIG. 1C

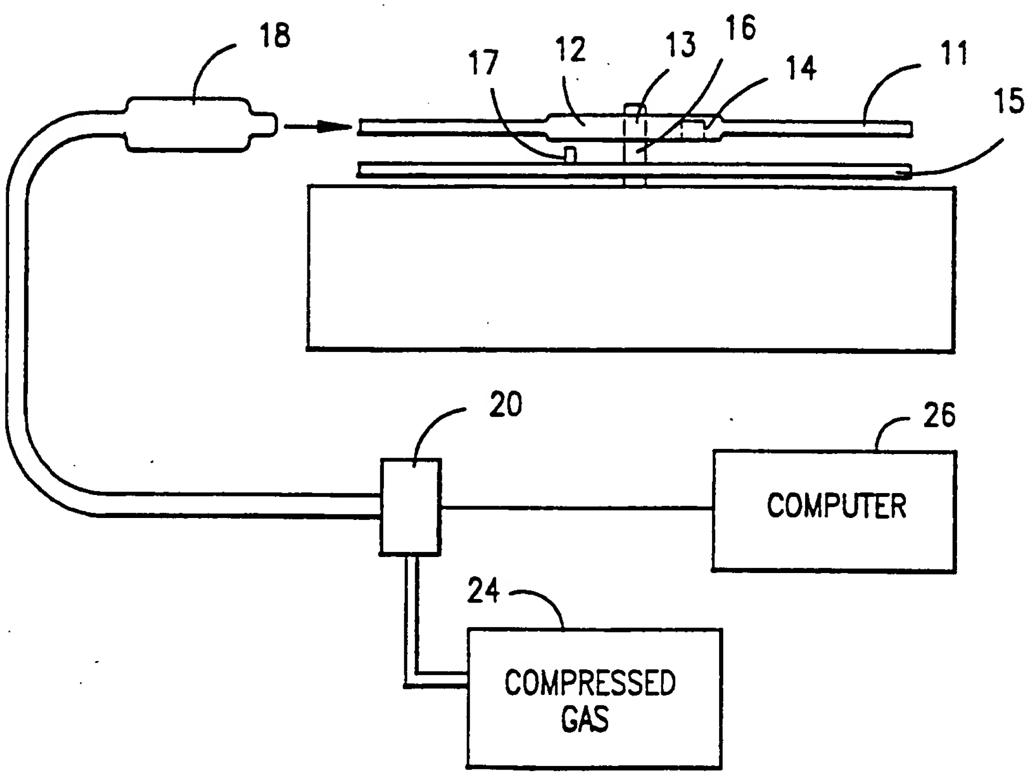

18
17
12
13
16
14
11
15
20
26
COMPUTER
24
COMPRESSED
GAS

FIG. 2

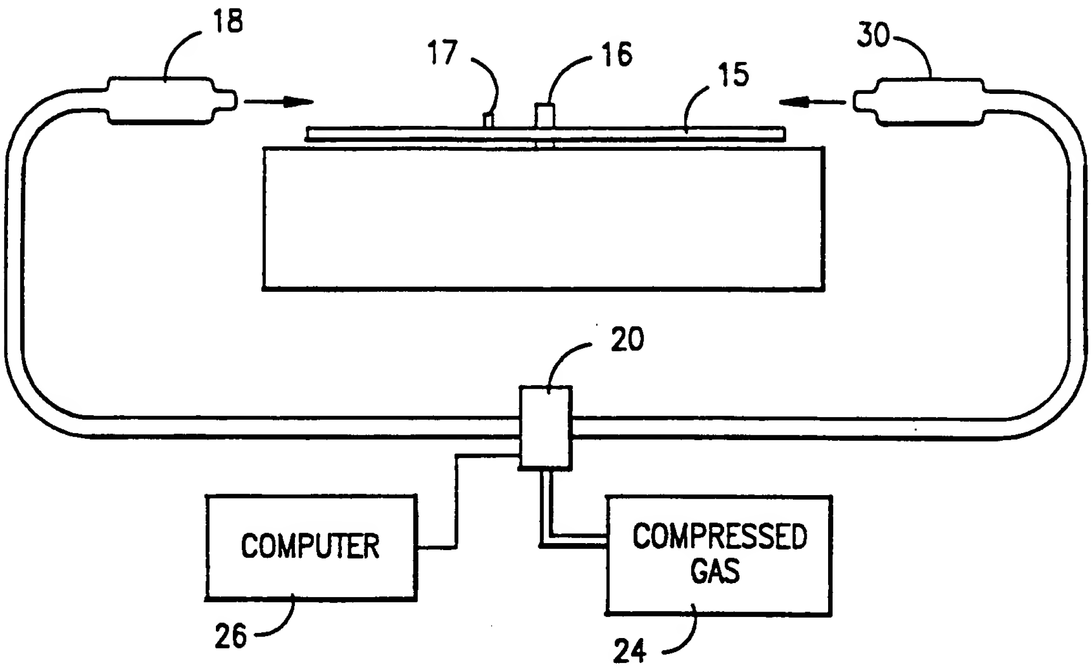
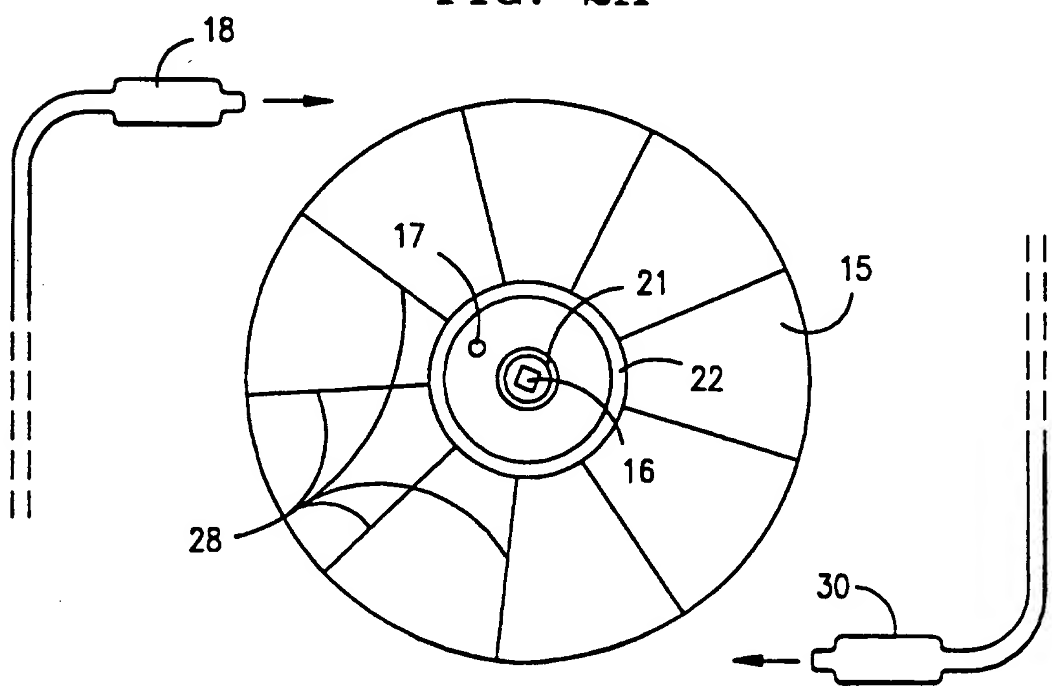

18
17
16
15
30
20
COMPUTER
26
COMPRESSED
GAS
24

FIG. 2A


18
17
21
15
22
16
28
30

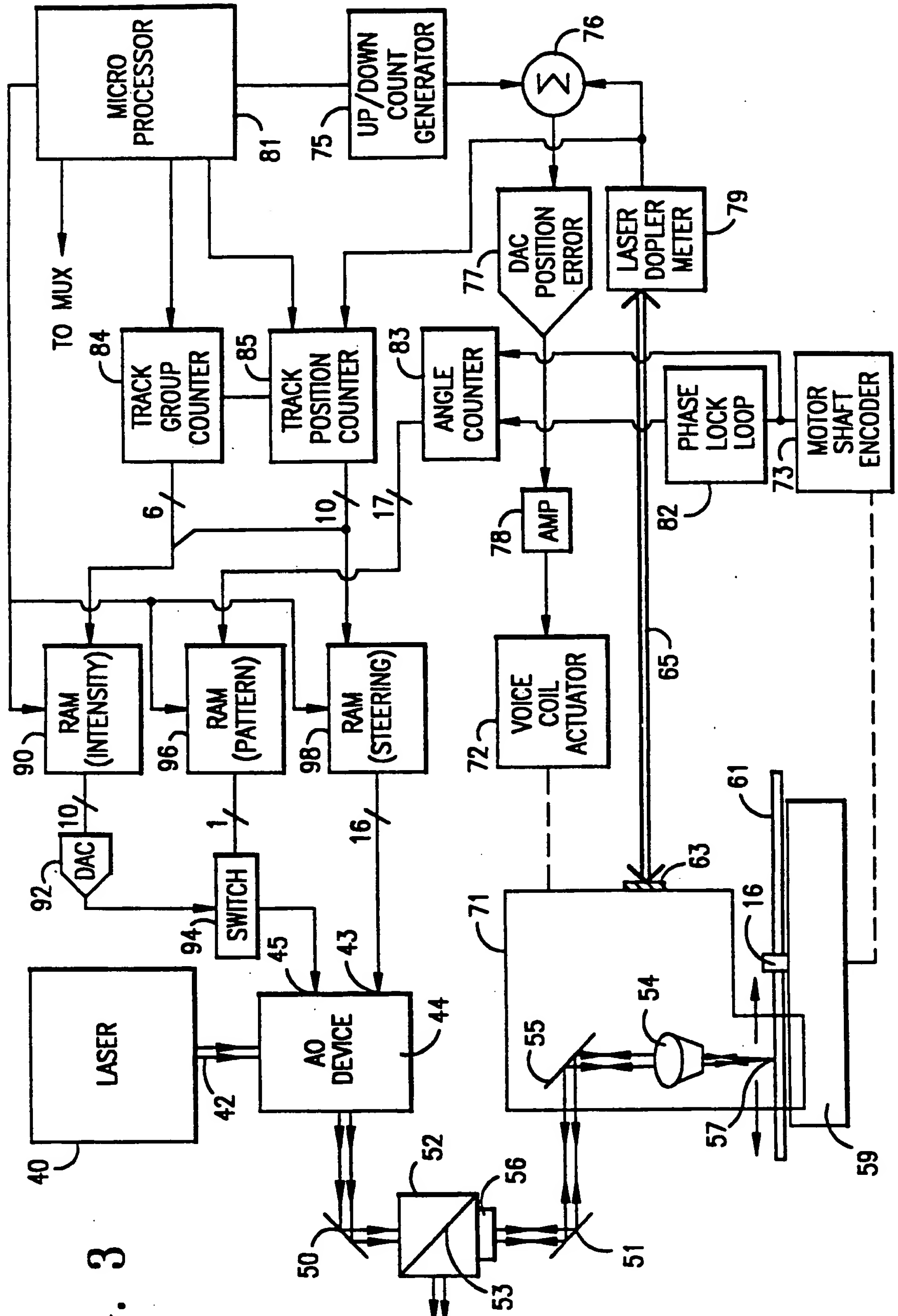

MICRO PROCESSOR
UP/DOWN COUNT GENERATOR
DAC POSITION ERROR
LASER DOPLER METER
TO MUX
TRACK GROUP COUNTER
TRACK POSITION COUNTER
ANGLE COUNTER
PHASE LOCK LOOP
MOTOR SHAFT ENCODER
AMP
VOICE COIL ACTUATOR
RAM (INTENSITY)
RAM (PATTERN)
RAM (STEERING)
DAC
SWITCH
LASER
AO DEVICE
76
81
75
77
79
84
85
83
82
73
78
6
10
17
90
96
98
72
65
10
1
16
92
94
45
43
63
71
61
16
54
55
44
42
40
57
59
52
56
50
53
51

FIG. 3

FIG. 4

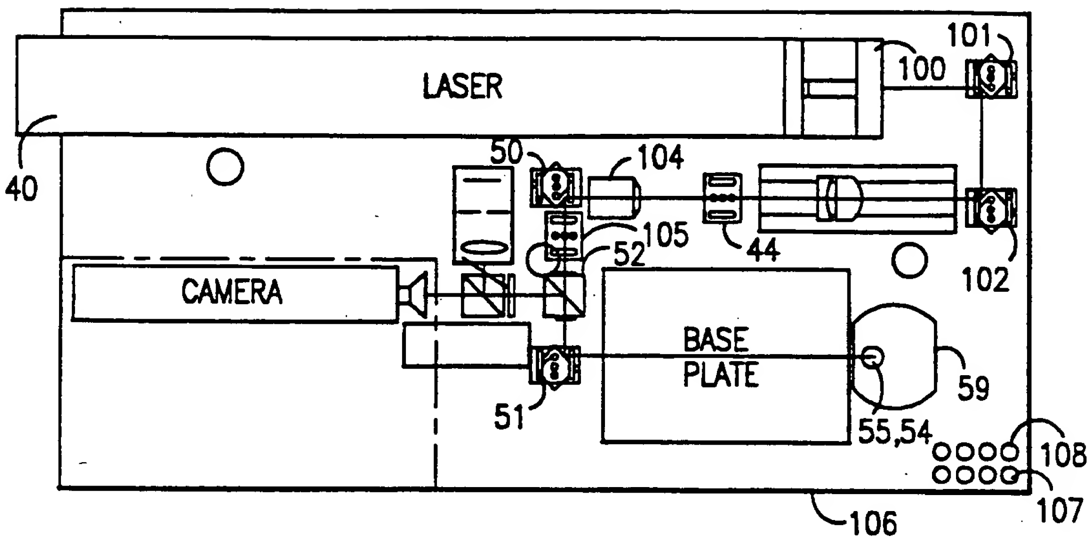


FIG. 5

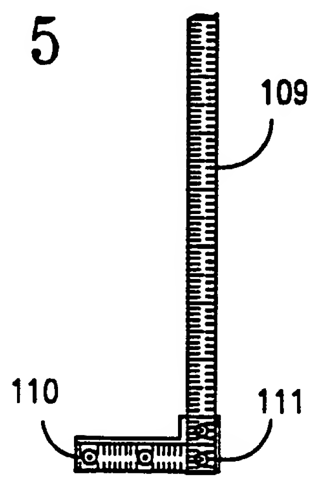


FIG. 5A

FIG. 5B

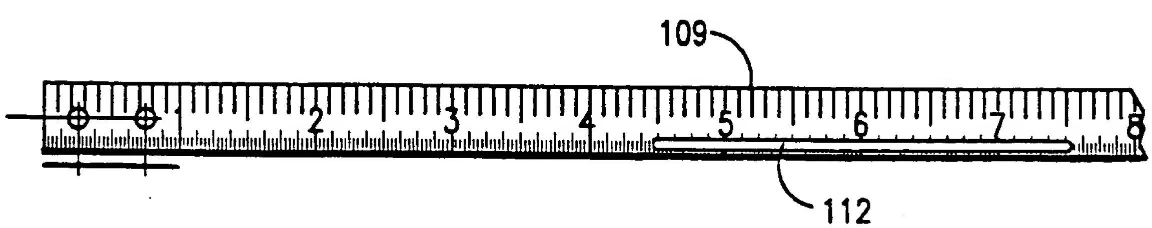
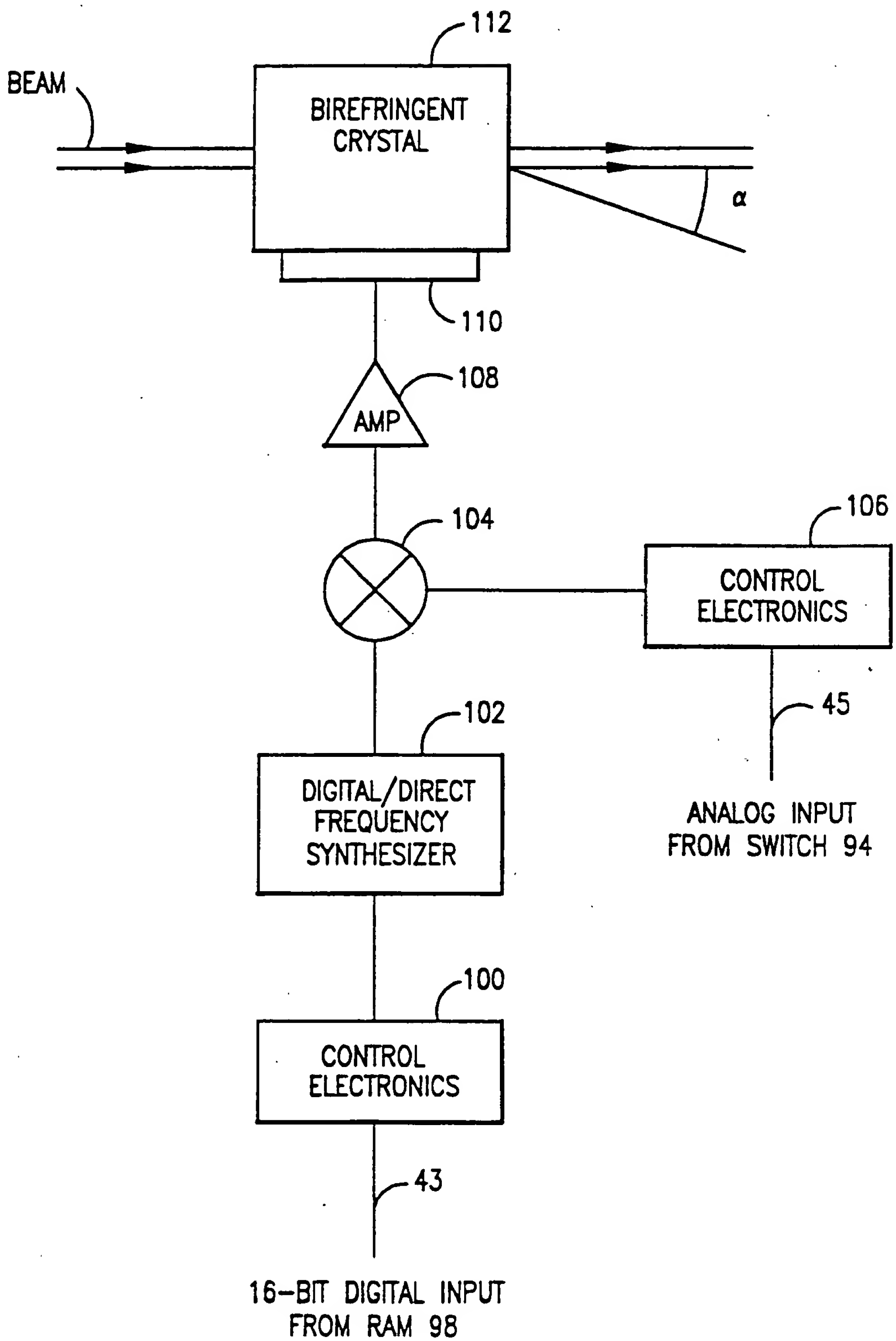


FIG. 6


112
BEAM
BIREFRINGENT CRYSTAL
α
110
108
AMP
104
106
CONTROL ELECTRONICS
45
ANALOG INPUT FROM SWITCH 94
102
DIGITAL/DIRECT FREQUENCY SYNTHESIZER
100
CONTROL ELECTRONICS
43
16-BIT DIGITAL INPUT FROM RAM 98

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/05230

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B23K 26/14
US CL :219/121.68
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 219/121.69, 121.84; 369/44.1, 44.41; 360/135; 264/104

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4,406,939 (GOLKER) 27 September 1983, see entire document.	---
A	US, A, 4,958,245 (ROTH, ET AL.) 18 September 1990, see entire document.	---
A	US, A, 5,065,387 (ROTH, ET AL.) 12 November 1991, see entire document.	---
A	US, A, 5,120,927 (WILLIAMS, ET AL.) 09 June 1992, see entire document.	---
A	US, A, 5,210672 (IVERS, ET AL.) 11 May 1993	---

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 AUGUST 1993	08 OCT 1993
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer Clarence Albritton CLARENCE ALBRITTON
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